

# Can common forest bird species tolerate disturbances in neighbouring areas? A case study of the Vuosaari Harbour construction in southern Finland

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Urbanization and other human activities can lead to decreasing animal populations in nearby areas. The impact of human activities may vary depending on the characteristics of the areas and region or on the strength of the disturbance. We investigated forest bird population changes in an EU Natura 2000 area during the construction of the new Helsinki Vuosaari Harbour in southern Finland in 2002–2011 as part of an environmental impact assessment. We evaluated whether the changes observed were linked with the harbour construction work by comparing the populations at sites near the development with those corresponding values obtained from national common bird monitoring in southern Finland. The mean population changes of 23 boreal forest bird species that inhabited the Natura 2000 area and southern Finland were significantly and positively correlated, but the population inside the Natura 2000 study area also showed lower mean numbers (a mean decline of 9% occurred over the study period). Our case study emphasizes the importance of intensive monitoring before, during and after work at the construction site and in the surrounding areas to detect actual changes in the populations.



## 1. Introduction

The ecological effects of urbanization and other human activities on the environment have been widely studied (McDonnell *et al.* 2009, Niemelä 2011). Biodiversity often differs between urban

and rural areas, and in general the population sizes and diversity of species are lower in urban areas, where the impact of human activities is usually high (Jokimäki & Suhonen 1993, McKinney 2008, Garaffa *et al.* 2009). Commonly mentioned negative factors that may impact bird populations

include noise, disturbance, habitat change, collisions with structures or vehicles, environmental pollution etc. Urbanization can lead to specific behaviours. For example, low-frequency songs lose their potency under noisy urban conditions, and birds use higher-frequency voices in urban environments (Slabbekoorn & Peet 2003, Halfwerk *et al.* 2011a, Slabbekoorn *et al.* 2012) to ensure their songs are heard through the environmental noise.

The impact of urbanization is not always negative, and urbanization and disturbance may even have positive effects on some species, e.g., due to displacement of predators (Leighton *et al.* 2010) or by creating suitable habitat patches (Aunins & Avotins 2018). The effects of moderate urbanization may vary significantly among groups; e.g., most plant studies (approximately 65%) indicate increasing species richness with moderate urbanization, whereas most invertebrate and vertebrate animal studies indicate decreasing species richness (McKinney 2008). However, the number of species may peak at an intermediate disturbance level, as has been reported in some bird studies (Jokimäki & Suhonen 1993, Meffert & Dziocik 2013, Yrjölä & Santaharju 2015).

Several studies have shown that artificial structures and general anthropogenic disturbances (Avery 1979), traffic noise and road mortality (Reijnen & Foppen 1995, Forman & Alexander 1998, Trombulak & Frissell 2000, Coffin 2007, Fahrig & Rytwinski 2009) or construction of windmill parks (Lucas *et al.* 2007) may negatively affect populations. The effects of harbour construction have not been studied widely, probably because harbours are large infrastructure projects that are only built occasionally. Many of the publications regarding harbours have examined their effects on water ecosystems (Dauvin *et al.* 2010, Smith *et al.* 2010). Dredging of shipping channels increases sedimentation, which strongly impacts the benthic fauna and chemical composition and suspension of solids in water.

Evidence suggests that noise disturbance and increased mortality caused by traffic may reduce the breeding success of birds (Foppen & Reijnen 1994, Parris & Schneider 2008, Halfwerk *et al.* 2011b). One Finnish study showed that the nesting success of Pied Flycatchers *Ficedula hypoleuca* (Pallas) was lower near roads, probably due to collisions with vehicles (Kuitunen *et al.* 2003). How-

ever, a forest bird study in Sweden found no general differences in forest bird populations with distance from roads (Helldin & Seiler 2003). Further investigation is therefore required to elucidate how artificial construction (roads, factories, mines) affects boreal forest bird populations.

A new harbour had been planned for Helsinki as early as the mid-1960s, and the Vuosaari Harbour project was implemented in 1992, when city authorities initiated planning. A Natura 2000 area is situated near the site of Vuosaari Harbour (F10100065, “Mustavuoren lehto ja Östersundomin lintuvedet”), with a minimum distance less than 300 m. In addition, a new railway bridge now crosses one of the bays of this area, and road tunnels were dug under a forest subarea. Before the project was approved, environmental authorities and nature protection organizations argued that construction of a new harbour and road connections could adversely affect breeding bird populations. As a part of the permit to build the harbour, mandatory investigation of the potential effects of harbour construction on the Natura area values was requested.

This investigation included monitoring programmes of the watershed and fisheries, plant populations, ground and surface waters, and bird species and populations (Koskimies 2001, Heikonen 2008). The objective of these programmes was not only to prevent possible significant detrimental changes, but also to document the information obtained from the project and monitor the environment before, during and after construction. The monitoring programmes were carried out as a cooperative project between the Helsinki Environment Centre and the Port of Helsinki.

The potential impact of disturbance to wildlife can best be analysed using a before-after-control-intervention (BACI) approach, whereby species are monitored before and after the disturbance and then compared with a reference group area where no disturbances have occurred during the same period (de Lucas *et al.* 2005, Sansom *et al.* 2016). Monitoring of our case-study area was initiated in 2002, and construction work began in 2003 after the breeding season. The monitoring continued three years after the harbour was opened in 2008. Here, we investigate the impact caused by the construction work of a large harbour area (the harbour and its road and railway connections) on common

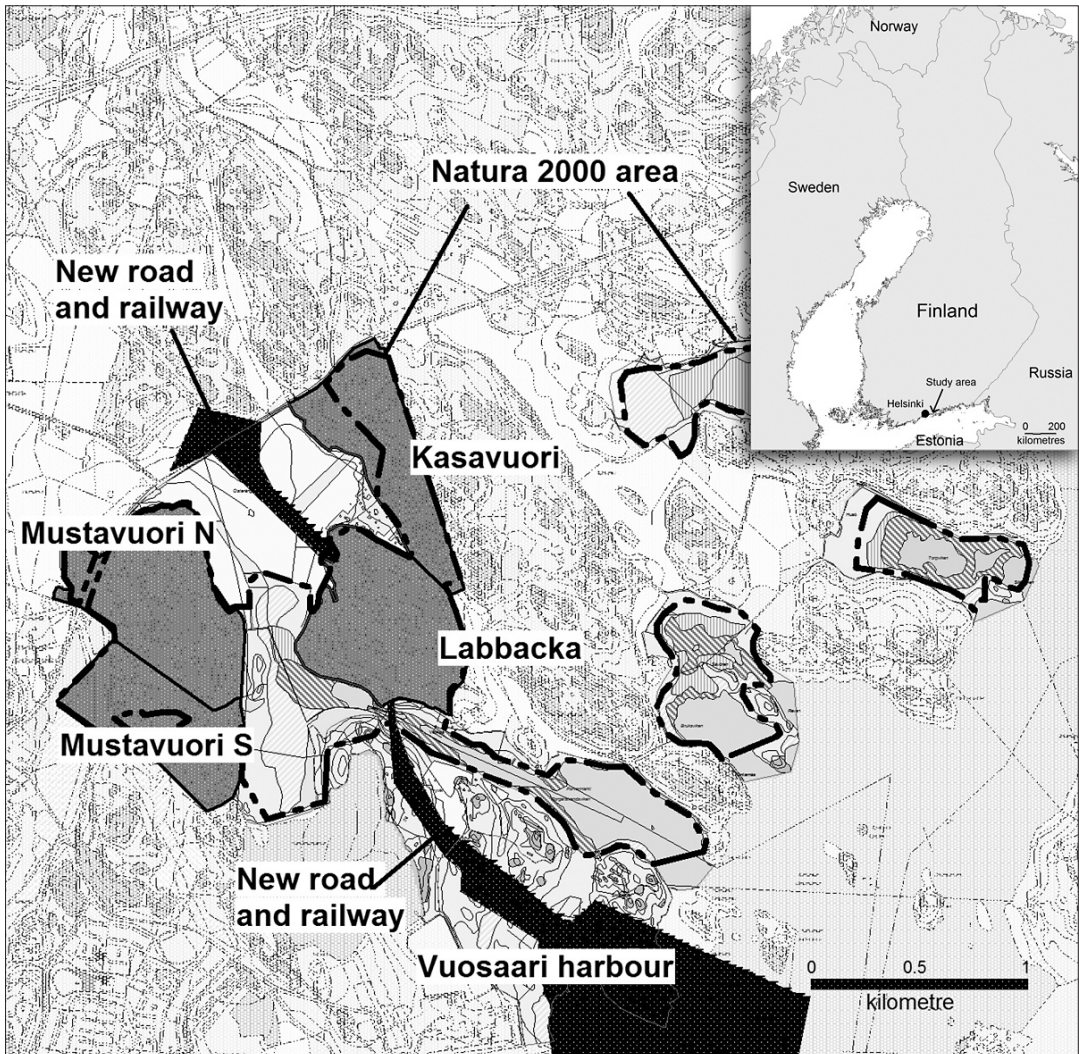


Fig. 1. Map of the study area, showing the survey sites in dark grey, road construction area and harbour in black and the Natura 2000 area marked with a dashed line (comprises several subareas).

forest birds of a nearby Natura 2000 protection area.

First, we compared the population changes observed in our study area with those observed in southern Finland to determine whether they were correlated. Second, we compared the populations between the subareas with tunnel construction with the other Natura 2000 areas to ascertain whether they differed. Based on previous studies (Jokimäki & Suhonen 1993, Foppen & Reijnen 1994, McKinney 2008), we hypothesized that the building of a new cargo harbour and its associated road infrastructure would negatively affect bree-

ding forest bird populations, especially in the sub-area closest to the road, railway tunnels and railway bridge construction sites. We expected that disturbance due to construction and roads would result in declining populations (Reijnen *et al.* 1995), and that the development of populations close to the harbour would differ from the population development of the same species in southern Finland. We also hypothesized that local forest bird population dynamics would be associated with changes over a wider area of southern Finland, due to large-scale drivers such as rising temperature or habitat changes in nonbreeding

Table 1. Study area biotopes (hectares and percentages). The data were derived from digital mapping data obtained from the National Land Survey of Finland.

Biotope (hectares)	Mustavuori North	Mustavuori South	Kasavuori	Labbacka	Total
Coniferous or mixed forest	38.4 (79.8%)	24.5 (72.7%)	18.7 (55.8%)	32.7 (73.3%)	114.3 (71.5%)
Agricultural area	0.1 (0.2%)	–	–	0.7 (1.6%)	0.8 (0.5%)
Meadow	0.1 (0.2%)	1 (3.0%)	–	–	1.1 (0.7%)
Rock	8.9 (18.5%)	3.9 (11.6%)	13.5 (40.3%)	11.3 (25.3%)	37.6 (23.5%)
Wooded swamp	0.6 (1.3%)	4.4 (13.1%)	1.1 (3.3%)	–	6.1 (3.8%)
Garden	–	–	0.3 (0.9%)	–	0.3 (0.2%)
Total	48.1 (100.0%)	33.7 (100.0%)	33.5 (100.0%)	44.6 (100.0%)	159.9 (100.0%)

grounds (Laaksonen & Lehtikoinen 2013, Fraixédas *et al.* 2015).

## 2. Materials and methods

### 2.1. Study areas

The study area is located in Helsinki, northeast of the Vuosaari district (60°14.52' N, 25°9.07' E), which along with the four subareas named are shown in Fig. 1. The distance to the city centre is 13 km and to the nearest suburbs 500 m. The new harbour is located south of the adjacent study area, but the new road-traffic connection to and from the harbour runs via a tunnel dug under the forested area. The study area is mainly surrounded by fields and small-housing areas with gardens. The forest continues outside the Natura 2000 area on its eastern border. The total study area was 159.9 ha of forests in the Natura 2000 area.

During the environmental impact assessment (EIA) process, the monitored forested area monitored was split into four subareas representing slightly different biotopes, although their size was small enough to be studied during a single morning. The biotopes of the various subareas are shown in Table 1. The biotope classifications used were based on data obtained from the National Land Survey of Finland. This classification resulted in an overall biotope distribution of the area, overlooking small biotope patches, e.g., small luxuriant grove-like forest patches associated with the mixed-forest class. The only artificial change in biotopes during the monitoring years was the building of tunnels under the Labbacka subarea, where a total of 0.5 ha of forest was cut (see Fig. 1).

Several tens of hectares of forest near the protected Natura 2000 area were clear-cut to make way for the new Vuosaari Harbour. More space was obtained for the harbour by filling in part of the seabed adjacent to the original sea-land margin with landfill material. A new 3-km-long road and rail traffic corridor with tunnels and a railway bridge was built. The final size of the new harbour area is approximately 150 ha, with 1500 m of piers for use by container ships in the harbour. Approximately 6 million m<sup>3</sup> of mud and clay were dredged away, and twice as much sand and crushed rock were dumped onto the seabed for constructing the foundations of the harbour ([www.portofhelsinki.fi](http://www.portofhelsinki.fi)).

The possible effects of the Vuosaari Harbour construction on nearby forest bird populations were investigated in the “Mustavuoren lehto ja Östersundomin lintuvedet” Natura 2000 area, which is protected through the Bird Directive and the Nature Directive. The Bird Directive annex I species observed in the area include the Common Tern *Sterna hirundo* L., European Nightjar *Caprimulgus europaeus* L., Barred Warbler *Sylvia nisoria* (Bechstein), Whooper Swan *Cygnus cygnus* (L.), Wood Sandpiper *Tringa glareola* L., staging only, Spotted Crake *Porzana porzana* (L.), Red-backed Shrike *Lanius collurio* L., Red-breasted Flycatcher *Ficedula parva* (Bechstein), Hazel Grouse *Bonasa* (now *Tetrastes*) *bonasia* (L.), Corncrake *Crex crex* (L.) and Ruff *Calidris pugnax* (L.), staging only.

The effects of harbour construction were investigated by using monitoring programmes planned for use during the EIA phase. The programmes included monitoring of the watershed and fisheries, plant populations, ground and sur-

face waters and birds (Koskimies 2001, Heikkinen 2008). The objectives of these programmes were to alert planners and engineers to prevent possible significant changes and to document the effect by monitoring the environment at the sites before, during and after construction. The monitoring programmes were carried out as a cooperative project under the auspices of the Helsinki Environment Centre and the Port of Helsinki. Bird population monitoring in the forested areas was initiated two years before construction commenced and continued for two years until after the opening of the Vuosaari Harbour in 2008; thus, the entire study period lasted from 2002 to 2011.

## 2.2. Subareas of the study site

The Mustavuori subarea was further divided into two smaller subareas (Fig. 1), both of which are rocky and wooded in their centres. The forests were mainly mixed, interspersed with wider grove areas on the fringes, supporting *inter alia* hazel *Corylus L.* bushes. Wooded remnants of swamps are situated in the southern part of the subarea, which includes a small strip of meadow. The minimum distance of Mustavuori North varies from 200 m to the new traffic routes to 1.8 km to the harbour facilities, while the corresponding distances from Mustavuori South are 700 m and 1.5 km. The Itäväylä main road is situated directly on the north-western side of Mustavuori forest.

The Kasavuori and Labbacka subareas are rocky and more rugged than the Mustavuori area (Fig. 1). The high elevated grounds of Kasavuori in particular are covered with bare rock (more than 40% of the area), and the fairly open tree stand is dominated by pine *Pinus L.* These subareas vary more in altitude than Mustavuori and include small sparsely wooded remnants of swamps.

The northern end of Kasavuori is bordered by the Itäväylä road. The western part is bordered by the Österängen suburban area, which has small houses and gardens; the eastern border is forested. There are small patches of mixed forest and wide areas of windfall. The Labbacka subarea is located to the south of Kasavuori. The forested area is bordered by arable agricultural fields in the west. Due to its rounded shape, the area can be considered a uniformly forested area with characteristic rocky

ridges. The undergrowth of the rocky areas is scarce, and pines are the dominant tree species. Some luxuriant forest patches also occur in the dells.

The minimum distance of Kasavuori varies from 200 m to the new traffic routes to 1.6 km to the harbour premises, while the corresponding distances from Labbacka are 0 m and 1.1 km. The Itäväylä road passes through the northern end of Kasavuori forest. Two road tunnels and one railway tunnel were constructed under the Labbacka subarea after 2004 and were opened to traffic in November 2008. The area impacted by the tunnel construction was 0.5 ha within the Labbacka subarea. Nearly 10,000 vehicles use these roads daily on weekdays and 6,000 daily on weekends, with an additional 10 trains passing through the subarea daily (average estimation year 2011).

## 2.3. Territory mapping

We repeated the territory mapping yearly between 2002 and 2011. We followed the protocol for bird census studies in Finland used by the Finnish Museum of Natural History (Koskimies & Väisänen 1988). We estimated the location and number of territories using 10 separate mappings performed by walking through the study areas between late April and late June. Each subarea was mapped wholly during one morning, 10 times per season. We designated an area as a territory when a single bird or a pair was observed in approximately the same position during three or more mappings and at least one of these observations showed territorial behaviour (song, alarm call, territorial fighting or parent bird carrying food to a nest).

## 2.4. Population trends in southern Finland

Bird populations in our study area may vary simultaneously with populations over wider comparable areas. We therefore compared the species-specific populations at the study site with the corresponding populations of the same species elsewhere in southern Finland (south of 61°14' N). We used the common bird-monitoring data of Finland coordinated by the Finnish Museum of Natural History from the same study years (2002–2011).

Table 2. Population trends and sample sizes of 23 common forest bird species in the Vuosaari Natura 2000 forest area (VS) and in southern Finland (SF) in general over the 10 year study period, based on calculation with the TRIM program. Only those species with sufficiently large sample sizes for comparison are included. Significant slopes in the various areas are in bold.

Species	VS Slope $\pm$ SE	VS N	SF Slope $\pm$ SE	SF N
Hazel Grouse ( <i>Bonasa bonasia</i> )	0.0005 $\pm$ 0.0355	5	0.0052 $\pm$ 0.0227	37
Wood Pigeon ( <i>Columba palumbus</i> )	-0.0217 $\pm$ 0.0331	9	<b>0.0151 <math>\pm</math> 0.0067</b>	639
Tree Pipit ( <i>Anthus trivialis</i> )	0.0011 $\pm$ 0.0158	18	-0.0108 $\pm$ 0.0060	738
Winter Wren ( <i>Troglodytes troglodytes</i> )	-0.0174 $\pm$ 0.0572	8	0.0054 $\pm$ 0.0159	82
Dunnock ( <i>Prunella modularis</i> )	0.0190 $\pm$ 0.0308	10	0.0174 $\pm$ 0.0115	229
European Robin ( <i>Erithacus rubecula</i> )	<b>0.0283 <math>\pm</math> 0.0121</b>	44	<b>0.0291 <math>\pm</math> 0.0077</b>	729
Eurasian Blackbird ( <i>Turdus merula</i> )	0.0000 $\pm$ 0.0096	40	<b>0.0341 <math>\pm</math> 0.0068</b>	634
Song Thrush ( <i>Turdus philomelos</i> )	<b>0.0637 <math>\pm</math> 0.0235</b>	22	<b>0.0416 <math>\pm</math> 0.0073</b>	667
Redwing ( <i>Turdus iliacus</i> )	-0.0302 $\pm$ 0.0328	13	-0.0077 $\pm$ 0.0077	595
Wood Warbler ( <i>Phylloscopus sibilatrix</i> )	<b>0.0664 <math>\pm</math> 0.0198</b>	16	-0.0232 $\pm$ 0.0131	151
Willow Warbler ( <i>Phylloscopus trochilus</i> )	<b>-0.0995 <math>\pm</math> 0.0229</b>	30	<b>-0.0150 <math>\pm</math> 0.0041</b>	2,412
Goldcrest ( <i>Regulus regulus</i> )	<b>-0.0892 <math>\pm</math> 0.0268</b>	17	<b>-0.0715 <math>\pm</math> 0.0095</b>	229
Garden Warbler ( <i>Sylvia borin</i> )	<b>0.0963 <math>\pm</math> 0.0383</b>	7	<b>0.0208 <math>\pm</math> 0.0062</b>	678
Blackcap ( <i>Sylvia atricapilla</i> )	0.0627 $\pm$ 0.0408	8	<b>0.0801 <math>\pm</math> 0.0141</b>	137
Spotted Flycatcher ( <i>Muscicapa striata</i> )	0.0407 $\pm$ 0.0354	7	0.0076 $\pm$ 0.0101	267
Pied Flycatcher ( <i>Ficedula hypoleuca</i> )	<b>0.0582 <math>\pm</math> 0.0276</b>	11	<b>0.0173 <math>\pm</math> 0.0083</b>	379
Willow Tit <i>Poecile montanus</i>	-0.0682 $\pm$ 0.0609	4	<b>-0.0421 <math>\pm</math> 0.0141</b>	119
Coal Tit ( <i>Periparus ater</i> )	<b>-0.1267 <math>\pm</math> 0.0479</b>	7	0.0084 $\pm$ 0.0204	59
Blue Tit ( <i>Cyanistes caeruleus</i> )	0.0141 $\pm$ 0.0267	15	0.0036 $\pm$ 0.0092	335
Great Tit ( <i>Parus major</i> )	<b>-0.0222 <math>\pm</math> 0.0105</b>	40	<b>0.0225 <math>\pm</math> 0.0051</b>	860
Eurasian Treecreeper ( <i>Certhia familiaris</i> )	-0.0860 $\pm$ 0.0522	7	<b>-0.0574 <math>\pm</math> 0.0171</b>	79
Eurasian Siskin ( <i>Carduelis spinus</i> )	-0.0235 $\pm$ 0.0190	15	-0.0112 $\pm$ 0.0071	656
Chaffinch ( <i>Fringilla coelebs</i> )	-0.0010 $\pm$ 0.0076	118	-0.0006 $\pm$ 0.0034	4,006

The monitoring data included both point counts (a mean of 14 point-count routes annually, min–max: 12–17, 20 observation points in each) and line transects (45, 17–73). The majority of the census sites (56%) were from fixed-position line transect routes with systematic sampling, established in Finland since 2006 (Lindström *et al.* 2015). The remaining census sites were based on free-choice locations of volunteer workers, but the sampling sites were placed so that they would represent the overall habitat availability in the nearby area (Koskimies & Väisänen 1988).

We compared only the populations of bird species that mainly breed in forests (Laaksonen & Lehtikoinen 2013), for which we observed at least three pairs annually in both our Vuosaari monitoring and the common bird monitoring of the Finnish Museum of Natural History, resulting in a total of 23 study species (Table 2). Furthermore, in comparing the populations of the subareas within the Natura 2000 sites, we used all the common forest bird species for which we observed a mean of

at least two pairs per year in Labbacka and the other subareas. We were able to use only data on 14 forest species in this analysis (Supplementary Table 1).

## 2.5. Statistical analyses

The common bird-monitoring data of the Finnish Museum of Natural History include observation gaps; thus, we calculated the population size for each species, using the TRends and Indices for Monitoring data (TRIM) program (Pannekoek & van Strien 2001). TRIM is an open-source software package that is a commonly used tool in bird monitoring throughout Europe ([www.ebcc.info](http://www.ebcc.info)). The program calculates *inter alia* overdispersion and serial correlation and interpolates missing observations, using a log-linear Poisson model. TRIM calculates annual growth rates and annual abundance indices. We used only general observations (annual additive growth rates) in this study.

Although no observation gaps were found in the Vuosaari data, we calculated the growth rates for this area, using the same program, which made it easier to compare the growth rates between the Vuosaari Harbour area and comparable sites in southern Finland. In Vuosaari, each subarea constituted a census unit, while in the surrounding areas we used a sum of the observations in a point-count route or a line transect.

First, we tested whether the species-specific population growth rates in the Vuosaari study area were explained by the corresponding growth rates based on data from southern Finland, using linear-major axis regression (package *lmodel2* in R). We used major axis regression instead of normal regression to account for the uncertainty in both the  $x$  and  $y$  variables. Second, we used the site-specific counts to analyse whether the population changes of the species differed between the study area and the surrounding monitoring sites in southern Finland that were subjected to analysis. This was done using the GLMM (generalized linear mixed model) statistical procedure (package *glmm AD Model Builder glmmADMB* in R; Fournier *et al.* 2012).

We used the most common 23 forest bird species (Table 2) in both analyses. The model site-specific counts were explained by year, region (construction area or surrounding areas) and their interaction. Census location and species were random factors, and the random annual slopes of the species were also included because the populations of the various species could have increased or decreased. Due to the potential overdispersion and large number of zeros in the data, we ran the model using Poisson and negative binomial error distributions with and without zero-inflation. These four model options were compared, using the small-sample-size-corrected Akaike information criterion (AICc) (Burnham & Anderson 2004).

In the second approach, we compared the temporal changes in the local populations at the Natura 2000 site by comparing the population sizes of the subarea situated closest to the construction area (Labbacka) with the sum of the population sizes of the other three subareas (Kasavuori, Mustavuori North and South). We compared the temporal changes in numbers of the forest bird species, using GLMM. The modelling was carried out in two

steps. In the first step, we compared the full model with the Poisson and negative binomial error distributions, based on the AICc. In comparison to regional analyses, here we did not use zero-inflated models, because the data rarely included zeros. The distribution of the top-ranked model obtained in this first step was subsequently used in the second step. The annual species-specific population size in the full model was the dependent variable, and the year, site and their interaction were the explanatory variables, the log-transformed area size was an offset variable and the species was a random factor. In the second step, we compared the full model with the model without the interaction based on AICc. The null hypothesis was that the linear changes in bird numbers between both areas were not significantly different. Significant interactions with year and site would reveal that the mean temporal changes in both areas were different. In both GLMM analyses, visual inspection of the residual plots clearly revealed no deviations from homoscedasticity or normality. We used R version 3.4.1 (R Core Team 2017) to run the statistical analyses of our data.

### 3. Results

During 2002–2011, 64 species were observed and categorized as possible breeding species (species with territory) in the Vuosaari study area. The annual number of territories varied from 473 to 573 and the number of species from 41 to 49 (Table S1). The mean bird densities during the study period in each subarea were as follows: 223 pairs per km<sup>2</sup> in Kasavuori, 254 pairs per km<sup>2</sup> in Labbacka, 449 pairs per km<sup>2</sup> in Mustavuori (North) and 332 pairs per km<sup>2</sup> in Mustavuori (South).

Of the 23 species, five and eight increased significantly in Vuosaari and southern Finland, respectively, whereas four species decreased significantly in both areas. The populations of 23 forest bird species in Vuosaari were significantly associated with the species' population growth rates in southern Finland during 2002–2011, since the major axis regression coefficient differed from zero, but the coefficient was significantly above 1, which suggested that the Vuosaari populations decreased and increased more strongly than the populations of the corresponding species in southern

Table 3. Parameter estimates of a generalized linear mixed model (GLMM) explaining population changes in the Vuosaari study area (V) and in southern Finland (SF) for 23 bird species.

Variable	$B \pm SE$	$z$	$P$
Intercept	$-14.490 \pm 5.671$	-2.56	0.011
Year	$0.008 \pm 0.003$	2.81	0.005
Area (V vs. SF)	$34.691 \pm 20.463$	1.70	0.090
Year: Area (V vs. SF)	$-0.017 \pm 0.010$	-1.71	0.088

Finland [ $b = 1.80$ , 95% confidence interval (CI) 1.06–3.37].

Furthermore, the intercept of the regression was slightly, but significantly, negative [ $-0.01$ , 95% CI  $-0.011$  to  $-0.003$ ], which suggests that the Vuosaari populations decreased more than populations in southern Finland in general. In the GLMM analyses, the model with the zero-inflated negative binomial error distribution was clearly the top-ranked model (Table S2). These GLMM analyses showed that the populations of 23 forest bird species were significantly increasing in southern Finland (outside Vuosaari), but tended to be smaller in Vuosaari than in southern Finland (interaction between year and area,  $P = 0.088$ ; Table 3). The outcomes of both the major axis regression and GLMM analyses suggest that the annual growth rates were about 1% smaller in Vuosaari than in comparable areas elsewhere in southern Finland, which is equivalent to about 9% lower population abundances throughout the study period.

There were no differences in the populations between the subarea closest to the disturbance and the other subareas (the model with interaction between year and subarea showed a 1.98 higher AICc value than the model without interaction). Since the more complicated model showed a higher AICc value than the simple model, the additional variable, i.e. interaction, can be considered as an uninformative parameter (*sensu* Arnold 2010). Thus, we investigated only the model without the interaction term. This model indicated that the mean population densities were smaller in the subareas closest to the disturbance (Labbacka) than in the other subareas inside the Natura 2000 area throughout the study period ( $b = -0.18 \pm 0.04$ ,  $z = 4.43$ ,  $P < 0.001$ ).

## 4. Discussion

Our study showed that many changes occurred in the species and territory numbers of birds in the forested areas near Vuosaari Harbour during the study years. However, a large portion of the population changes reflected similar changes throughout a wider area in southern Finland. Previous nationwide studies have shown that long-distance tropical migrants, northern species and species living in agricultural environments have declined in Finland (Virkkala & Rajasärkkä 2011, Laaksonen & Lehikoinen 2013). In addition, some forest bird species have also declined in southern Finland (Fraixedas *et al.* 2015). These changes are probably linked with changing conditions at non-breeding sites (long-distance migrants), climate warming (northern species) and changes in farmland and forest land use. Climate warming has additionally shifted the population densities of birds that have hitherto inhabited Finland towards the north, which has also affected the populations of birds in southern Finland (Virkkala & Lehikoinen 2014). Our findings support the concept that local population dynamics are not independent of larger-scale population dynamics in the surrounding areas (e.g., Lindström *et al.* 2013).

Our results also show that the construction of Vuosaari Harbour together with the ancillary traffic routes and other possible human impacts outside the Natura 2000 area probably caused an estimated 9% population decrease in common forest bird species at the Natura 2000 site over the entire 10-y study period. The results of previous studies of road and noise impacts on bird populations have varied, depending on the area and bird species. Negative effects have been observed in some studies, and forest bird occupancy patterns or densities have changed. Increasing noise nevertheless reduces bird numbers (Reijnen *et al.* 1995, Goodwin & Shriver 2010). Two previous case studies in the forested areas of Sweden and Finland have only been able to detect weakly negative or neutral effects caused by road disturbance (Kuitunen *et al.* 1998, Helldin & Seiler 2003). Some of the negative effects of roads can be masked by positive effects, such as new roadside habitats or edge effects (Helldin & Seiler 2003). We focused especially on forest species in this study; thus, it is unlikely that such species would have benefitted from edge ef-



fects. The negative effects were not stronger in the subarea closest to the construction area.

It is important to bear in mind that the harbour construction probably resulted in negative impacts on local forest bird populations outside the Natura 2000 area, because over 50 ha of forest were clear-cut for constructing the harbour. On average, the density of forest birds in southern Finland is several hundred pairs per km<sup>2</sup> (Solonen *et al.* 2010). Using this average density, we can roughly estimate that the construction of Vuosaari Harbour caused the loss of at least 100 forest bird territories near the Natura 2000 area. Compared with the yearly clear-cut area of more than 18,000 ha for the entire province of Uusimaa (Statistics Finland 2015), the proportion of this lost forested area in Vuosaari was small (0.27%). The loss of natural habitats in the vicinity of the Natura 2000 area was partly compensated by the restoration and rehabilitation of the nearby Natura 2000 areas. Before the harbour construction, there had already been a need for restoration, especially for wetlands, as described by Koskimies (1998).

There are several plausible explanations for the differences in populations we observed between the Natura 2000 site and southern Finland in general, which can be linked with avoidance due to increased noise and disturbance (Reijnen *et al.* 1995, Goodwin & Shriver 2010) or increased mortality of birds due to collision with vehicles (Summers *et al.* 2011, Husby 2016). First, the new road to the harbour does not directly cross any of these forested areas, but does go through a tunnel under one area. Therefore, we do not believe that forest bird species would be strongly influenced by additional mortality in moving within the forested area, although we cannot exclude the possibility that increased mortality could have contributed to the reduced bird abundances at the Natura 2000 site. Second, the new road likely increased noise disturbance in the area, which may have led to avoidance of the study site in comparison to outside areas. Third, common forest bird species in the Boreal Zone may be rather tolerant of medium-level disturbances, such as road-traffic noise. The fact that the study site had already been situated rather near the urban areas of Helsinki could have modified the bird community composition at the Natura 2000 site towards more disturbance-tolerant species before the study period. Fourth, we should

also bear in mind that all the study species are common forest birds. We did not consider the less common and perhaps more disturbance-sensitive species (such as owls and other birds of prey) in our study, due to their small number of territories. Fifth, from an EIA standpoint, there is a need for classifying species sensitivity along a gradient of disturbance intensity and investigating the disturbance impact for both common and uncommon species. This would, however, require a much larger geographical approach than that used in our present study design.

Our sample was not very large (e.g., in terms of the number of species and pair observations), which may have confounded the detection of any potential negative impact. However, the sample sizes were still large enough to show that the populations in these two areas were rather strongly and positively correlated. Sample sizes in EIA case studies are typically rather small, which may explain the difficulty in detecting any impacts, despite the BACI design. A meta-analysis of similar case studies is needed to evaluate the scale of the impacts of construction works on local populations. We must stress that the common bird-monitoring data are not purely control area data, but rather are reference data, since management activities may also have occurred at some of the census sites.

Under optimal conditions, the comparison sites should have been based on a systematic sampling scheme only. In Finland, such a scheme was initiated in 2006, several years after this study was begun. However, since the majority of these data come from fixed-position line transects of systematic sampling (Lindström *et al.* 2015), we believe that these data generally describe the overall situation of bird populations in southern Finland. In addition, even though the method used in Vuosaari (territory mapping) was different from that used in the national counts and the species densities may have differed between counting methods, we assumed that the populations of species should be comparable.

Our results indicate that the construction work on the harbour together with other possible human impacts outside the Natura 2000 area probably had a negative impact on the populations of common birds at the Natura 2000 site (approximately 9% decline throughout the study period). The EIA pro-

cesses prior to actual land-use activities are important tools for mitigating the potential negative impacts on animal populations. Without these EIA processes in the preparation and planning of the construction work in the harbour, the loss of biodiversity values at the nearby Natura 2000 site could have been much higher. This emphasizes the importance of intensive monitoring before, during and after the construction work to predict potential and detect actual changes in the populations.

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### **Häiriöiden vaikutus metsälintupopulaatioihin: tapaustutkimus Vuosaaren satama-alueen rakentamisen vaikutuksesta**

Kaupungistuminen ja muu ihmisen toiminta voivat johtaa lähialueiden eläinpopulaatioiden vähenemiseen. Ihmistoiminnan vaikutus voi vaihdella alueen ominaisuuksien tai häiriön voimakkuuden mukaan. Vaikutus voi johtua esimerkiksi melun aiheuttamasta häiriöstä, tai tien rakentamisen aiheuttamasta kuolleisuuden kasvusta törmäysten takia. Tutkimme Helsinkiin rakennetun uuden Vuosaaren sataman rakentamisen mahdollisia vaikutuksia viereisen Natura 2000 -alueen metsälintujen populaatioihin vuosina 2002–2011. Lintukantojen seuranta oli osa sataman ympäristövaikutusten arviointia.

Tutkimuksessa arvioimme, ovatko mahdollisesti havaitut muutokset lintujen populaatioissa

yhteydessä sataman rakentamiseen, ja poikkeavatko metsälintupopulaatioiden muutokset samalla ajanjaksolla Etelä-Suomessa havaituista lintupopulaatioiden kehityksistä. Metsälintujen kartoituksessa menetelmänä oli 10 kerran kartoitus ja tutkimuksessa oli neljä osa-aluetta, joista Labbackan alue oli lähinnä satamaa ja sen läpi rakennettiin liikennetunnelit.

Tutkimuksen perusteella lähinnä satamaa oleen osa-alueen lintupopulaatioiden muutokset eivät poikenneet muista alueista. Sen lintupopulaatioiden tiheys oli alueiden keskiarvoja pienempi, mutta sen saattaa selittää alueen karummat biotoopit. Vuosaaren metsälintupopulaatioiden muutoksia verrattiin myös Luonnontieteellisen Keskusmuseon Etelä-Suomesta keräämään seuranta-aineistoon. Oletimme, että jos sataman rakentamisella on paikallisesti haitallinen vaikutus, metsälintupopulaatioiden kehitys sataman lähellä poikkeaisi Etelä-Suomen metsälintupopulaatioiden muutoksista vastaavalla ajanjaksolla. Yhteensä tähän vertailuun voitiin käyttää 23 metsälintulajin tietoja.

Tutkimuksen perusteella Natura 2000 -alueen ja Etelä-Suomen vertailuaineiston 23 metsälintulajin populaatioiden muutokset korreloivat positiivisesti keskenään. Toisin sanoen, Vuosaaren tutkimusalueella lintukannat muuttuivat pääsääntöisesti saman suuntaisesti kuin laajemmalla alueella Etelä-Suomessa. Muutokset (positiiviset tai negatiiviset) olivat kuitenkin voimakkaampi Vuosaaren alueella. Tutkimuksen perusteella metsälintujen populaatioiden kasvu vuodessa oli Vuosaaresa keskimäärin 1 % pienempää kuin vertailuaineistossa, mikä johtaa noin 9 % pienempään populaation kasvuun koko tutkimusjakson aikana.

Yhteenvetona voidaan todeta, Vuosaaren sataman rakentamisen ei suoraan voitu osoittaa vaikuttaneen haitallisesti viereisen Natura 2000 -alueen metsälintujen populaatioihin, vaan populaatioiden kehitys oli samankaltaista kuin laajemmalla alueella Etelä-Suomessa. Metsälintupopulaatioiden kasvu oli kuitenkin tutkimusalueella hieman hitaampaa, mikä voi johtua sataman rakentamisesta, tai muusta ihmistoiminnan vaikutuksesta lähi-alueella. On myös mahdollista, että negatiivisia vaikutuksia voi olla harvalukuisimpiin lajeihin, joiden aineisto ei riittänyt tilastolliseen analyysiin. Tutkimus osoitti hyvin, miten tarpeellista on tehdä laajoja ja pitkäaikaisia lintupopulaatioiden seuran-

toja suurissa rakennushankkeissa, jotta voidaan osoittaa mahdolliset muutokset lintupopulaatioissa.

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### Online supplementary material

- Supplementary Table 1. Numbers of bird territories at the Natura 2000 site divided into four subareas over the 10-y study period.
- Supplementary Table 2. Small-sample-size-corrected Akaike information criterion AICc differences and AIC weights of models with different error distributions.